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The difference on Arthropod communities' structure within show caves and wild caves in Gunungsewu karst area, Indonesia

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ABSTRACT

This study was conducted to determine the differences on Arthropod communities' structure and climatic-edaphic factors within wild caves and show caves in Gunungsewu karst area, also analyze the climatic and edaphic components that give the strongest influence on Arthropods community. Arthropod Sampling was done by hand collecting, pitfall and bait traps, and Berlese extractor. The measured components of climatic factor comprise light intensity, air temperature, RH, and CO_2 level, while the edaphic comprise soil temperature, SOC, N, P, soil moisture, and pH. Data wereanalyzedby richness, diversity, evenness, and dissimilarity indices measurement. We also conducted statistical analyze through Pearson correlation. All Arthropod samples were classified into six classes, 30 orders, and 209 morphospecies. The dark zones of wild caves with low human disturbance have lower richness, diversity, and evenness than the dark zones of show caves. Species richness of Arthropods in Show Caves is not always lower than wild caves, but the populations of common cavernicolous Arthropods (*Rhaphidophora* sp., *Trachyjulus tjampeanus*, *Charon* sp. and *Sarax javensis*) in show caves are almost smaller than wild caves. The Arthropod communities of wild caves with low disturbance have high dissimilarity with show cave communities. Highly disturbed show caves possess higher air temperature, light intensity, CO_2, soil temperature and pH compared to wild caves particularly in the dark zone, while soil moisture, SOC, N, and P are lower. Light intensity, soil temperature, and SOC show the highest coefficient of correlation values with the indicators of Arthropods community. In conclusion, the recent study indicates that there are differences in the community structure of Arthropods and climatic-edaphic conditions within wild caves and show caves. Light intensity, soil temperature, and SOC give the strongest influences on Arthropod communities' structure.

***Key words** : Climatic, Edaphic, Cave Management, Conservation.*

Introduction

Gunungsewu is one of karst areas in Indonesia that has been designated as a conservation area and recognized as a Global Geopark Network (GGN UNESCO). Gunungsewu has many karst caves that hold great potentials in both scientific and economic values. Currently, many wild caves in Gunungsewu

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have been developed into show caves. Developing caves as the tourist attraction is considered more sustainable and environmentally friendly than another potential use of caves such as for an extractive industry.

Unfortunately, show cave is often managed less wisely and economically oriented only. This management has caused many caves to lose their specific environmental characters due to artificial changes made by cave managers. Furthermore, some of the caves have even developed into mass tourists and over-exploited. Whereas, the cave has unique and typical environmental characters such as the absence of natural light, stable temperature, high relative humidity, high level of CO_2 and low O_2. Also, the lack of food sources (Palacious-Vargas *et al*., 2011; Simoes *et al*., 2015; Bento *et al*., 2016). These characters make cave ecosystem become one of the most fragile ecosystems (Culver and White, 2012; Jones, 2016). Some previous studies indicated that cave development for tourism identified as one of the majors' threat to cave biodiversity and ecosystem (Macud and Nuneza, 2014).

Most animals living inside caves were considered as "cavernicolous" and classified to accidental, trogloxene, troglophile, and troglobite according to the degree of using cave environment for their life cycles (Barr, 1963; Romero, 2009). Arthropods are the most abundant cavernicolous fauna that plays critical roles in cave ecosystem. They are maintaining the sustainability of food webs and the balance of cave ecosystem (Rahmadi, 2002). Changes in cave environmental conditions due to tourism activities can disrupt the Arthropods community then damage the entire cave ecosystem.

Until now, evaluation for show caves management in Indonesia is still scarcely undertaken. Adverse impacts of tourism activities on cave ecosystems are not yet widely studied. Information about the previous condition of show cave ecosystems is often insufficient, making trying to monitor the dynamics of ecosystem changes that occur. Comparison of the ecological condition of caves that have been developedinto show caves with unspoiled caves (wild caves) can be used as an alternative way to learn the influences of tourism activities on cave ecosystems sustainability.

Considering their essential roles in cave ecosystem, Arthropods can be used as an indicator to describe the condition of cave ecosystem. The present study aims to determine the differences in Arthropods communities' structure and climatic-edaphic factors within wild caves and show caves in Gunungsewu karst area, also analyze the climatic and edaphic components that give the strongest influences on Arthropods community. The result of this study is expected to take accurate account of the regulatory arrangements and evaluation of show caves management.

Materials and Methods

This study was conductedatthreeshow caves (Gong, Tabuhan, Semedi) and threewild caves (Paesan, Kalisat, Ponjen) of Gunungsewu karst area located in the middle of Java Island, Indonesia during December 2016-February 2017. Every cave is divided into threecommunities determined based on cave zones: light, twilight and dark zones(Culver and White, 2005).

Arthropods Sampling

Arthropods collection was done by hand collecting, pitfall and baits traps, and soil extraction with Berlese extractor. The direct collection was done with the help of gloves, brushes, and tweezers for 90 minutes (30 minutes x 3 observers) in each zone. Pitfall traps were made by vial bottles (5 cm in diameter) and filled with 96% alcohol and glycerin (9:1 in ratio), while the bait traps based on Hunt and Millar (2001) design with cheese bait. Pitfall traps are installed in each cave zone of 5 pieces each, while the bait traps are two pieces and left for 48 hours. The Berlese extractor's modification used 15W bulb lamps and placed 20 cm above the samples. Samples of soil were taken as much as 1 liter (each zone 2 samples) and extracted for four days. All collected Arthropods are identified based on morphological characters to the lowest possible taxon level.

Abiotic Sampling

The abiotic measurements include climatic and edaphic factors. Climatic factor measurement was performed directly in the field. Light intensity was measured by lux meter (Lutron LX-107), air temperature and humidity by logger (eTemperature version 8.31), while CO_2 level by CO_2 meter (Telaire T7001). The measurement of edaphic factor comprises soil temperature was carried out directly in the field with soil thermometers. Besides, soil samples were collected and tested in the laboratory of the Agency for Agricultural Research and Development in Yogyakarta to measure the content of soil organic carbon (SOC), nitrogen (N), phosphate (P), soil pH, and moisture.

Data Analysis

The data were analyzed by calculating richness index according to Margalef:

D : $^{(S-1)}/_{Ln\ N}$(Dao-Hong, 2007)

Diversity and evenness indices according to Shannon-Wienner:

H′ : $-\sum_{i=1}^{n} \text{Pi} \ln \text{Pi}$ (Schowalter, 2011)

E_H : $^{H'}/_{Ln\ S}$ (Pielou, 1966)

Moreover, dissimilarity index according to Bray-Curtis:

Dissimilarity : $^{\sum_{i=1}^{n} |Xij - Xik|}/_{\sum_{i=1}^{n}(Xij + Xik)}$ (Schowalter, 2011).

The Dissimilarity index calculation and dendrogram of dissimilarity arrangement were performed using MVSP program version 3.1. The statistical analysis was taken through Pearson correlation test using SPSS software version 23.

Results and Discussions

Arthropods Taxa in All Caves

Arthropods collected from all caves consist of 6 classes, 30 orders, and 209 morphospecies. The number of morphospecies in each order can be seen in Table 1. Insecta possesses the highest species richness, followed by Arachnida, Collembola, Myriapoda (Diplopoda and Chilopoda), and Crustacea (Fig. 1).

Insecta is a class with the highest number of morphospecies (87 species). This type is known as

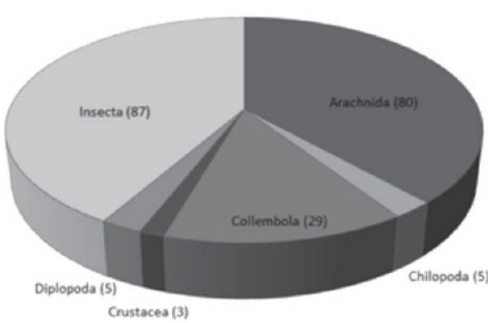

Fig. 1. Comparison of Arthropods Morphospecies number of each order.

Table 1. The number of Arthropods morphospecies in each order

No	Class	Order/Group	Number of Morphospecies
1	Arachnida	Acari	28
		Amblypygi	2
		Aranea	44
		Opiliones (Laniatores)	2
		Pseudoscorpiones	3
		Schizomida	1
2	Chilopoda	Geophilomorpha	2
		Lithobiomorpha	1
		Scolopendromorpha	1
		Scutigeromorpha	1
3	Collembola	Entomobryomorpha	20
		Poduromorpha	4
		Symphypleona	5
4	Crustacea	Isopoda	3
5	Diplopoda	Polydesmida	3
		Spirostreptida	2
6	Insecta	Blattodea	2
		Coleoptera	28
		Dermaptera	1
		Diplura	2
		Diptera	9
		Hemiptera	5
		Hymenoptera	20
		Isoptera	1
		Lepidoptera	1
		Microcoryphia	1
		Neuroptera	1
		Orthoptera	5
		Psocoptera	3
		Thysanoptera	1
		Immature Insect	7
		Total	209

the most abundant Arthropods almost in all types of ecosystems, it because they are highly adaptive to new environments and environmental changes (Gillot, 2005).All collected Insecta are classified to order of Blattodea (2 species), Coleoptera (28 species), Dermaptera (1 species), Diplura (2 species), Diptera (9 species), Hemiptera (5 species), Hymenoptera (20 species), Isoptera (1 species), Lepidoptera (1 species), Microcoryphia (1 species), Neuroptera (1 species), Orthoptera (5 species), Psocoptera (3 species), Thysanoptera (1 species), and larvae or immature insect (7 species).

Arachnida possesses the second highest morphospecies with 80 species. There are nine orders of Arachnida that are commonly known to have habitat in cave ecosystem and six orders of which can be found in this research (Howarth, 2009). Those six orders are Acari (28 species), Amblypygi (2 species), Aranea (44 species), Opiliones Sub Order Laniatores (2 species), Pseudoscorpiones (3 species), and Schizomida (1 species).

Collembola is separated from Insecta and become another different class. This separation is based on the presence of theventral tube in the first segment of collembolan abdomen (Suhardjono *et al.*, 2012). Collected Collembola specimens comprise 29 species and become the third rank of the highest morphospecies. The class of Collembola consists of 4 orders and 3 of which can be found in this study, they are Entomobryomorpha (20 species), Poduromorpha (4 species) and Symphypleona (5 species).

Chilopoda and Diplopoda (Sub Phylum Myriapoda) possess the same number of species (5 species). The Chilopoda that were found comprises 4 orders: Geophilomorpha (2 species), Lithobiomorpha (1 species), Scolopendromorpha (1 species), and Scutigeromorpha (1 species), while the Diplopoda consists of 2 orders: Polydesmida (3 species) and Spirostreptida (2 species).

Crustacea is the class with the least of species numbers compared to other classes (3 species). Members of this class are known to be more diverse and abundant in aquatic habitats than terrestrial ones. There are only two orders that are known to have habitat in the terrestrial environment, Amphipoda and Isopoda (Howarth, 2009; Romero, 2009). The 3 species collected in this study are classified into Isopoda from 3 different families, Philosciidae, Oniscidae and Armadillidae.

Arthropods found in this study are dominated by species acting as predators (54%) and decomposers

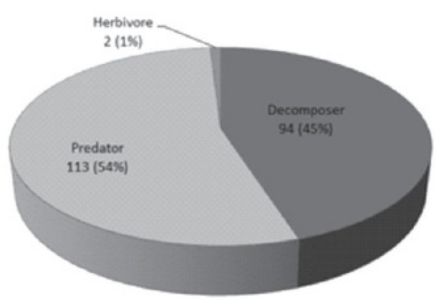

Fig. 2. Comparison of Arthropods according to roles in ecosystem

(45%) (Fig.2). Both groups are found to dominate in cave ecosystem and play very critical roles in it. Both groups will keep in the balance of each population so the balanced ecosystem can be achieved (Suhardjono and Ubaidillah, 2012).

Based on the morphological characters shown by the 209 Arthropods species found in the study, mostare classifiedas troglophile (96%), accidental (3%) and only 1% (2 species) that belong to troglobite (obligate cave species) (Fig. 3). These 2troglobite species are Isopoda (Family: Oniscidae) and one member of Acari (Sub-Order: Prostigmata). TroglobiticIsopod showsthe characteristic of troglomorphy in the form of depigmentation and diminished eyes, whereas Acari has depigmentation, diminishedeyes, and legs lengthening (Gunn, 2004; Romero, 2009; Culver and White, 2012).

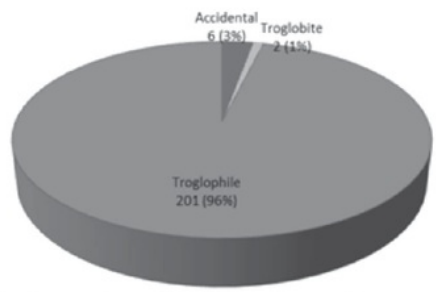

Fig. 3. Comparison of Arthropods according to cave adaptation category.

Arthropods Community Structures in each Cave

Changes in the structure of Arthropodscommunity as a result of tourism activities can be detected by comparing the arthropod communities that exists among caves that are still naturally preserved with caves that have been developedintoshow caves.

The results of richness index calculation (Fig. 4) show a similar pattern in all caves. The light zone possesses the highest species richness, followed by twilight zone and dark zone. The species richness tends to decrease with increasing distance from the cave entrance. This is due to the typical character of cave environment especially in the dark zone causing only certain species of Arthropods to survive in it.Fig.4also shows that species richness of terrestrial Arthropod in wild caves is not higher than in show caves.The species richness tends to vary among caves and does not depend on the type of cave management.

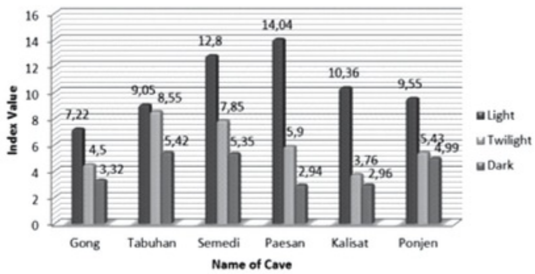

Fig. 4. Richness index

The highest species richness contributors to the entire cave arthropods come from light and twilight zones where the species found in these zones are predominantly species often found in the outside cave environment. Changes in environmental conditions due to tourist activity are thought to have a less significant effect on Arthropods living in these zones than groups living in the dark zone. It because of Arthropods living in these zones is more adaptive to environmental fluctuations.

Based on Fig.4, the species richness in the dark zone of wild caves tends to be lower than show caves, except for Ponjen Cave which is higher than Gong Cave. Even it is classified as awild cave, Ponjen possesses high-level disturbances record due to human activities during colonial periods. The pattern of richness index in dark zone indicates that human activities in caves have potential to increase species richness. High species richness is not a typical characteristic of cave ecosystems. Cave ecosystems are commonly known as ecosystems with lower species richness than other ecosystems (Culver and Pipan, 2009).

The results of diversity index calculation (Fig. 5) show a similar pattern to the richness index. The diversity index in light and twilight zones shows higher values than dark zone. This result indicates that Arthropods community in the dark zone has

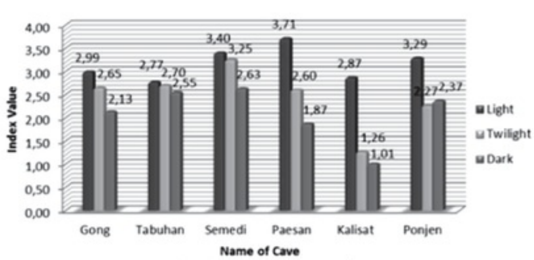

Fig. 5. Diversity index

higher pressures and instability than what occurs in light and twilight zones.

The typical conditions of cave environment require organisms to adapt to survive in the dark zone. In general, the dark zone is more dominated by species that have successfully adapted to life in this zone (Suhardjono and Ubaidillah, 2012).This is supported by the calculation of evenness index (Fig. 6) which shows that population among species in the dark zone of wild caves with low disturbance are smaller than light and twilight zones, also than the dark zone of show caves. This result indicates that the dark zone of wild caves have a high degree of dominance, while the dark zone of show caves and one wild cave with high disturbances (Ponjen) the populations of species are more evenly distributed. The species found to dominate in the dark zones of wild caves are *Rhaphidophora* sp., *Trachyjulus tjampeanus*, *Charon* sp., *Mimocerus* sp., Acari (2 species), and Insecta larvae (3 species).

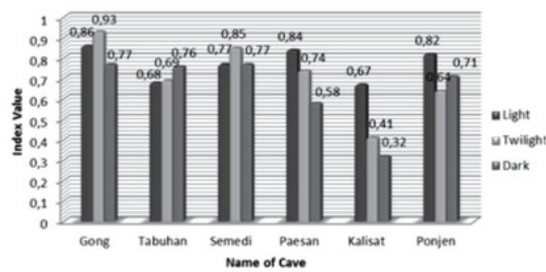

Fig. 6. Evenness index

Several common cavernicolous Arthropods species in Gunungsewu canbe found in all six caves used for thestudy, cave cricket (*Rhaphidophora* sp.), millipede (*Trachyjulus tjampeanus*), and Amblypygi (*Charon* sp. and *Sarax javensis*). These species are known to be related to each other in cave ecosystem. *Rhaphidophora* sp. and *Trachyjulus tjampeanus* have a role as decomposers, while Amblypygi serves as predator particularly for *Rhaphidophora* sp. The population of each species in the all six caves can be used as an indicator to detect the impact of human activities on current cave species populations.

Fig. 7 shows that all populations are almost smaller in show caves than wild caves. *Trachyjulus tjampeanus* population in Ponjen (wild cave) is lower than Semedi (show cave) because of the particular condition. Ponjen recently has smaller bats population size than Semedi. Massive human activities

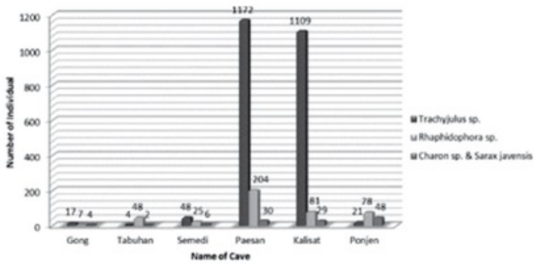

Fig. 7. Population of common cave species

during colonial periods in Ponjen had caused bat populations to decline and finally decreased guano availability which is the food for *Trachyjulus tjampeanus*. Besides, *Trachyjulus tjampeanus* and *Rhaphidophora* sp. are known to use the same type of organic material as food. Beside of the limited source of guano, small-size populations of *Trachyjulus tjampeanus* in Ponjen and Tabuhan are caused by losing in feed competition with *Rhaphidophora* sp.

The dissimilarity index is used as a basis for creatingdendrograms that will show the level of similarities among all communities. The dendrograms generated based on dissimilarity index are shown in Fig. 8.

Based on Fig. 8a, it can be seen that wild caves with low human disturbance (Paesan and Kalisat) have a high similarity of Arthropods community each other and both tend to differ substantially with the community in show caves. The 3 caves are classified as show caves (Gong, Tabuhan and Semedi) have asignificant similarity of Arthropods community each other. Also, a wild cave with high disturbance record (Ponjen) tends to be different from the other two wild caves, and it is more similar to show caves. These results prove that high human activities in a cave can cause changes in Arthropods community inside the cave.

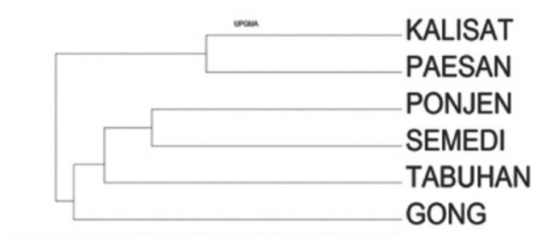

Fig. 8a. Dissimilarities of Arthropods communities among caves

The inter-zone dendrogram (Fig. 8b) is made to look in detail at which zone human activities give the most significant impact on Arthropods community, making the communities in wild caves with low disturbance tend to be different from caves having high human disorders. Based on Fig. 8.2, it can be seen that the community of dark zones of wild caves with low human disturbance (Kalisat and Paesan) have a high similarity each other and tend to differ significantly from other communities. The community of dark zone of a wild cave that has high human disturbance record (Ponjen) tends to be more similar to the dark zone communities of show caves. Also, the dark zones of show cave have high similarity with communities in light and twilight zones in all caves compared to the dark zones of wild caves with low disturbance. These results indicate that human activities give the most significantadverse impact on Arthropods community in the dark zone. Human disturbance, either directly or indirectly, can change the community character of thedark zone so that it becomes more similar to light and twilight zones.

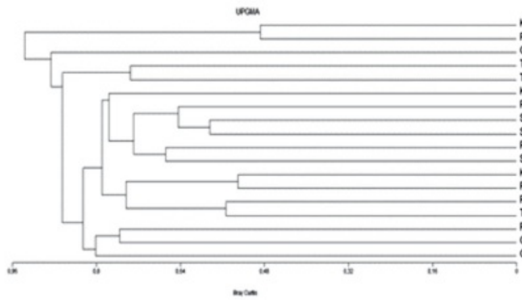

Fig. 8b. Dissimilarities of Arthropods communities among cave zones

The Differences on Climatic and Edaphic Factors

Abiotic parameters of cave environment have astrong association with biotic components living in it(Pellegrini and Ferreira, 2013; Simoes *et al.*, 2015). Climatic (microclimate) and edaphic factors are two mainabiotic parameters that will decide the community structures of Arthropods(Macud and Nuneza, 2014; Parwez and Sharma, 2014).The mean of climatic and edaphic factors measurements in every cave zone are shown in Table 2 and Table 3.

The difference on climatic conditions with in wild caves and show caves is indicated by the results of climatic measurements in the dark zone. Based on

Table 2, it can be seen that the dark zones ofshow caves with high human visits (Gong and Tabuhan) have higher air temperatures than dark zones of the 3 wild caves and 1show cave with low human disturbance (Semedi). The climatic difference that also looks significant is CO_2 level. Gong that has high human visits has higher CO_2level than other caves. The increasing number of visitors and duration of cave exploration could increase air temperature and CO_2in cave environment(Fernandez-Cortes *et al.*, 2011; Sebela and Turk, 2014).

Human activities do not cause high levels of CO2 in wild caves (Paesan and Kalisat) but because of the existence of thesignificant bats population. Bat population in acave known to produce CO_2, temperature, and humidity that can affect cave microclimate(Lundberg and McFarlane, 2009).The number of bats in Tabuhan and Gong isinsufficient, but they have high CO_2 levels.This proves that massive human activitiesin show caves will increase air temperature and CO_2 levels.

The difference inclimatic conditionsthat is also clearly visible is light intensity. Gong and Tabuhan have much higher light intensity than other caves, particularly in the dark zone. The light intensity of dark zone inthese both caves is even higher than twilight zone. This fact happens because of the presence of artificial lights installed by cave manager producing light pollution in cave alleys. Air humidity did not show any significant difference within show and wild caves. The relative humidity in all caves is relativelyhigh (above 90%).

Almost same with the climatic factor, the results of edaphic factor measurements in the dark zone are also more representative to explain the differences in edaphic conditions within wild caves and show caves. Based on Table 3, it can be seen that Gong has much higher soil temperature than other caves, but its soil moisture is much lower. The slightly different

Table 2. Measurement of climatic factor components

Com.	Air Temp. (°C)	Air RH (%)	Light In. (lux)	CO_2 (ppm)
Go T	26.44	102.56	162.50	4354.50
Go R	27.38	103.51	9.80	5085.90
Go G	27.01	102.04	13.90	6971.90
Tab T	23.83	97.24	69.84	436.16
Tab R	23.93	101.07	7.53	489.32
Tab G	25.52	100.33	9.37	1231.68
Sem T	24.49	94.28	1575.14	393.48
Sem R	24.01	98.34	7.15	400.60
Sem G	24.10	100.44	0.00	425.20
Pae T	23.51	100.67	1142.63	596.21
Pae R	24.42	101.48	1.11	1937.58
Pae G	25.01	101.72	0.00	3231.59
Kal T	23.60	97.63	517.57	973.10
Kal R	22.81	101.38	1.29	1612.95
Kal G	24.00	99.99	0.00	1771.14
Pon T	24.13	100.37	290.00	604.58
Pon R	24.01	100.08	1.63	668.32
Pon G	24.51	100.71	0.00	825.67

Table 3. Measurement of edaphic factor components

Com.	pH	SOC (%)	N-NH_4 (ppm)	P_2O_5 (ppm)	Moist. (%)	Temp. (°C)
Go T	7.92	0.96	165.9	2	25.07	25.53
Go R	8.18	0.93	136.8	4	20.72	26.40
Go G	8.59	0.12	11.64	29	11.13	28.00
Tab T	7.31	2.44	363.83	223	22.24	24.23
Tab R	7.29	1.47	259.04	64	21.88	23.76
Tab G	7.26	0.67	43.66	146	32.04	24.99
Sem T	7.51	0.75	145.53	26	20.66	25.95
Sem R	6.54	1.59	203.74	189	26.63	25.08
Sem G	6.82	0.46	66.94	128	26.68	24.80
Pae T	7.71	2.24	358	47	22.84	23.89
Pae R	7.79	3.39	311.43	91	39.2	23.91
Pae G	5.85	3.54	532.64	191	41.18	25.02
Kal T	7.56	1.5	218.3	35	22.22	21.74
Kal R	7.55	1.31	151.35	34	32.63	21.86
Kal G	6.76	3.39	392.93	150	31.65	23.49
Pon T	7.65	1.22	145.53	7	23.15	24.74
Pon R	7.37	1.77	232.85	95	24.56	24.79
Pon G	7.01	0.93	116.42	159	33.4	25.21

conditions occur in Tabuhan and Semedi which have soil temperature, and humidity tends to resemble with wild caves. Although Gong and Tabuhan are show caves with high human visits and there are electric lights in it, but the number of lights installed and the average number of visitors in Gong is much higher than Tabuhan. Besides, many of electric lights in Gong are installed very close to the ground, while in Tabuhan the lights installed far from the ground. The proximity of electric lights to the ground effects in the rise of soil temperature and the decrease in soil moisture around the presence of the lights. Besides, the low soil moisture in Gong caves also caused by the existence of concrete buildings that limits the pools with the soil around it, making the process of water penetration to the soil disturbed. Similar buildings can also be found in the dark zone of Semedi. It is the way soil moisture in the dark zone of Semedi relatively low even the soil temperature is moderate.

The soil chemical content consisting of pH, SOC, NNH_4, and P_2O_5 have interrelation patterns, particularly in dark zones. Based on Table 4, it can be seen that SOC, NNH_4, and P_2O_5 have positive correlations each other and those all 3 components have the negative correlation with soil pH. Soil pH tends to be low in zones that have much organic material, while the SOC, NNH_4 and P_2O_5 contents in those zones are relatively higher.

Based on edaphic measurements (Table 3) the dark zone of wild caves have more acidic soil pH and higher SOC, NNH_4, and P_2O_5 than show caves. Due to a significant amount of organic material piles in the form of bats guano. Guano is known to have acidic pH and contains high organic carbon, phosphate, and nitrogen (Sikazwe and Waele, 2004).

Correlation of Climatic-Edaphic with The Arthropod Communities' Structure

Based on Table 5, it can be seen that the climatic factor component having the strongest influence on Arthropod community is light intensity. It is indicated by the largest correlation coefficient value of this element with Arthropods community structure indicators compared to other climatic components. Light intensity has a very strong positive correlation with species richness (r = 0.802) and moderate correlation with diversity (r = 0,557). Light is the main source of energy for life. The existence of light allows plants (producers) to live and produce primary productivity (organic matter) through photosynthesis. Primary productivity is the source of a variety of other life (biodiversity) at the higher trophic level in ecosystems (Culver and White, 2005).

Table 5. Correlation of climatic-edaphic with Arthropod community structure indicators

Variables	Richness	Diversity	Evenness
Climatic	r		
Light Inten.	0.802**	0.577*	0.236
CO_2	-0.459	-0.276	0.161
Air Temp.	-0.331	0.031	0.495*
Air Humidity (RH)	-0.581*	-0.334	0.075
Edaphic	r		
pH	0.205	0.237	0.397
SOC	-0.055	-0.286	-0.484*
NNH_4	0.095	-0.161	-0.409
P_2O_5	-0.305	-0.244	-0.300
Soil Temp.	-0.186	0.203	0.557*
Soil Moist.	-0.420	-0.406	-0.426

**$P<0.01$ (2-tailed); *$P<0.05$ (2-tailed), r =Correlation Coeficient

Cave has specific environmental characters, i.e., no light, deprived of variety and source of nutrients and lower species richness compared to other ecosystems (Culver and Pipan, 2009). The existence of light in the dark zone of thecave would enhance the adverse effect on the survival of Arthropods community life in it. The presence of lights with high intensity and long duration of lighting time in show caves led to the growth of lampenflora. Lampenflora is the photosynthetic organism that lives in the cave

Table 4. Correlation among edaphic factors components

	pH	SOC	NNH_4	P_2O_5	Soil Moist
SOC	-0.467				
NNH_4	-0.517	0.932			
P_2O_5	-0.761	0.445	0.416		
Soil Moist.	-0.635	0.604	0.453	0.490	
Soil Temp.	0.261	-0.425	-0.381	-0.073	-0.386

due to the existence of artificial light (Culver and White, 2005; Mulec and Kosi, 2009). Lampenflora can be found easily in the dark zone of Gong and Tabuhan. Those mainly consist of bryophytes, pteridophytes, and algae colonies. Those photosynthetic organisms live attached to cave ornaments located close to the lamps. The existence of lampenflora in thecave will change the typical environmental characters of thecavethen affects the destruction of ornaments and cave fauna. It is because lampenflora can trigger deterioration of cave ornaments and enhance invasive fauna species (Castello, 2014).

Excessive lights caused by tourist activity in caves can also disrupt the survival of bat colonies (Mann *et al.*, 2002). If bats population decreases, the supply of guano which is the primary source of food for many Arthropods in the cave will be automatically reduced. This condition will indirectly result in the decline of current cavernicolous Arthropod populations as it has occurred in Gong and Tabuhan.

There are two components of edaphic factors that have the most substantial influence on Arthropod community structures compared to other edaphic components, and they are air temperature and soil organic carbon (Table 5). These two elements show different influences on Arthropods community structure. The soil temperature has a positive correlation with evenness ($r = 0.557$), while the SOC has a negative correlation with evenness ($r = -0.484$).

Increasing in soil temperature will affect the growth of evenness or suppress dominance. More prevalence indicates this condition among species populations in zones with higher air and soil temperatures. Soil temperature in the dark zones of wild caves with low human disturbance tends to be less than show caves having high human visits, and there is domination by standard Arthropod species in cave ecosystem. The increase in soil temperature due to tourism activities will potentially eliminate the dominance, in other words, will decrease the population of common Arthropod species in cave ecosystem.

SOC has the negative correlation with evenness, diversity and species richness. It means that cave zones that have a high SOC tend to be dominated by certain species and have lower richness and diversity. The dark zone of wild caves with low disturbance has higher SOC, but species richness and diversity tend to be low and dominated by common Arthropod species in cave ecosystem. This result is entirely different from a result obtained by Dao-Hong (2007) where the content of organic matter has high positive correlations with species richness and diversity.

The species richness and diversity are not necessarily determined only by the quantity of sources of organic material that serves as food, but also the quality of the organic matter. The heterogeneity of feed sources is considered to be one of the most critical factors (Culver and White, 2005). The dark zone of wild caves with low disturbance has higher SOC, but it is a lack in variation, which is only in the form of bats guano.

Conclusion

Arthropods found in wild caves and show caves at Gunungsewu karst area consist of 6 classes, 30 orders, and 209 morphospecies. Insecta has the highest species richness (87 species), followed by Arachnida (80 species), Collembola (29 species), Diplopoda (5 species), Chilopoda (5 species), and Crustacea (3 species). Species richness of Arthropods in Show Caves is not always lower than wild caves, but the populations of common cavernicolous Arthropod species in show caves is almost smaller. The dark zone communities of wild caves with low human disturbance have the high degree of dominance, while in show caves the populations among species tend to be evenly distributed. Dark zone communities of wild caves with low disturbance have low similarity with the communities in show caves and another wild cave that has high disturbance record. Show caves with high human visits have dark zones with air temperature, light intensity, CO_2, soil temperature, and pH relatively higher compared to less disturbing wild caves, while soil moisture, SOC, NNH_4 and P_2O_5 contents are relatively lower. Light intensity, soil temperature, and SOC give the most substantial influence on the Arthropod communities. The recent study proves that the management of Gong, Tabuhan, and Semedi caves have enhanced negative impacts on cave Arthropods community. The management should not be a model for new show caves development and need tobe evaluatedimmediately.

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